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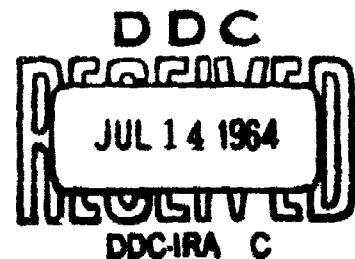
STUDIES OF AIR LOADS ON MAN

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MAY 1963**

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STUDIES ON AIR LOADS ON MAN

JOHN J. SWEARINGEN and ERNEST B. McFADDEN

ABSTRACT

Data obtained in three different studies related to measurement of forces on the body due to air movement are summarized. The effects of short duration blast forces on personnel seated or standing at various distances from openings during pressure loss, blast forces necessary to disorient the body from numerous positions, effect of clothing on the drag forces, and measurements of forces and moments on the body during wind tunnel tests are discussed and compared.

INTRODUCTION

The purpose of this report is to summarize the findings of our laboratory on the effects of air loads (wind forces) on man. These findings are discussed in relation to the sudden failure of a small area in a pressure envelope, the physical displacement of man in corridor-like areas and the aerodynamics of man.

PRESSURE ENVELOPE FAILURE

Experiments by Swearingen¹ simulated failure of a window in a pressurized aircraft. The

order of magnitude of safe distances of the occupant from the point of failure, i.e. the distance beyond which physical ejection or serious-to-fatal head injuries from impact are unlikely to occur, were shown. The tests involved rupturing a membrane in the window of a low pressure chamber (1350 ft³ capacity), maintained from 2 to 7.5 lb/in² below atmospheric pressure with an articulated dummy seated near windows of various dimensions. Minimal safe distances for a pressure differential of 6 lb/in² are reproduced in Fig. 1. It was not possible with the facilities available

MINIMAL SAFE DISTANCES FOR PROTECTION AGAINST THE WIND BLAST EFFECTS OF EXPLOSIVE DECOMPRESSION

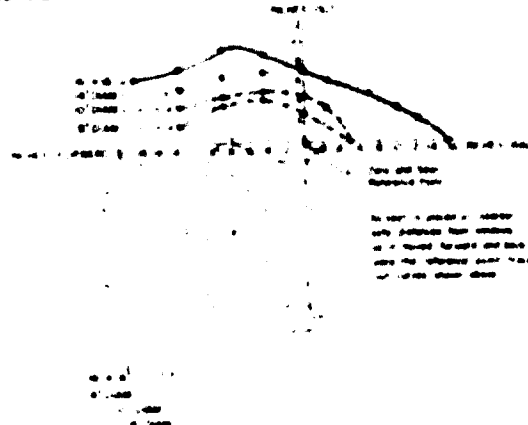


FIGURE 1. Minimal safe distance curves.

to reproduce closely the conditions of a window failure in flight, so the precise limits of distance for safety in various practical situations in aircraft remain unknown.

Subsequent experiments simulating failure of a large opening such as a door in a pressurized aircraft were also made using one subject.

The subject, wearing a safety harness attached to a slack cable, stood 24 in. in front of and facing a 75 in. by 37 in. opening covered by a diaphragm pressurized to 6.5 lb/in². The forces were surprisingly low despite the distance, relative sizes, and pressure differential involved. He was not blown from his feet but maintained balance by stepping forward. This might suggest that personnel working near pressurized doors could be protected by a simple restraining cable, if a need for this arose. The peak force in this experiment was found to be about 170 lb.

In chambers of larger size than the one used (1350 ft³), air loads would last longer and thereby have a greater tendency to displace the body. For continuous air loads equal to the magnitude of the maximum experienced in a decompression from a sea level equivalent to a pressure 6.5 lb/in² lower, the magnitude of the air load is estimated in Appendix I to be about twice that experienced here.

PHYSICAL DISPLACEMENT OF MAN BY AIR BLAST

One of the purposes of this series of experiments was to determine the magnitude of short duration air loads that would cause the subjects to lose their balance or to be otherwise physically displaced. The experiments were conducted in a space similar to corridor areas in aircraft as shown in Fig. 2. The duration of these forces was several tenths of a second. Figure 3 gives a sample oscillograph tracing. The various body positions studied are illustrated in Fig. 4. Note in Fig. 4 that shadographs were made of nude (shorts and shoes) subjects in order to obtain a sharp outline for area determinations.

PHASE I. MEASUREMENT OF DRAG FORCES

This study included measurement of maximum forces acting on the clothed human body (shirt, trousers and shoes) during equalization of a pressure difference of 6.5 lb/in² following puncture of a membrane separating a partially evacuated low-pressure chamber and a "wind tunnel" or collar at sea level pressure. The subjects assumed an upright or other position in the rectangular "wind tunnel" with the body oriented in various directions in relation to the air blast. The subject was supported upon a

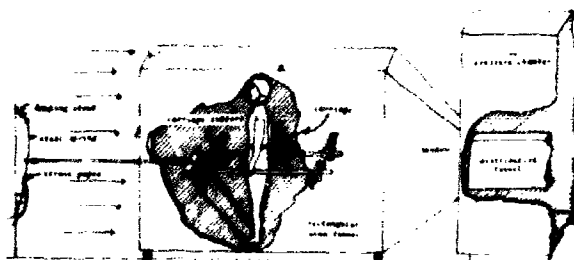
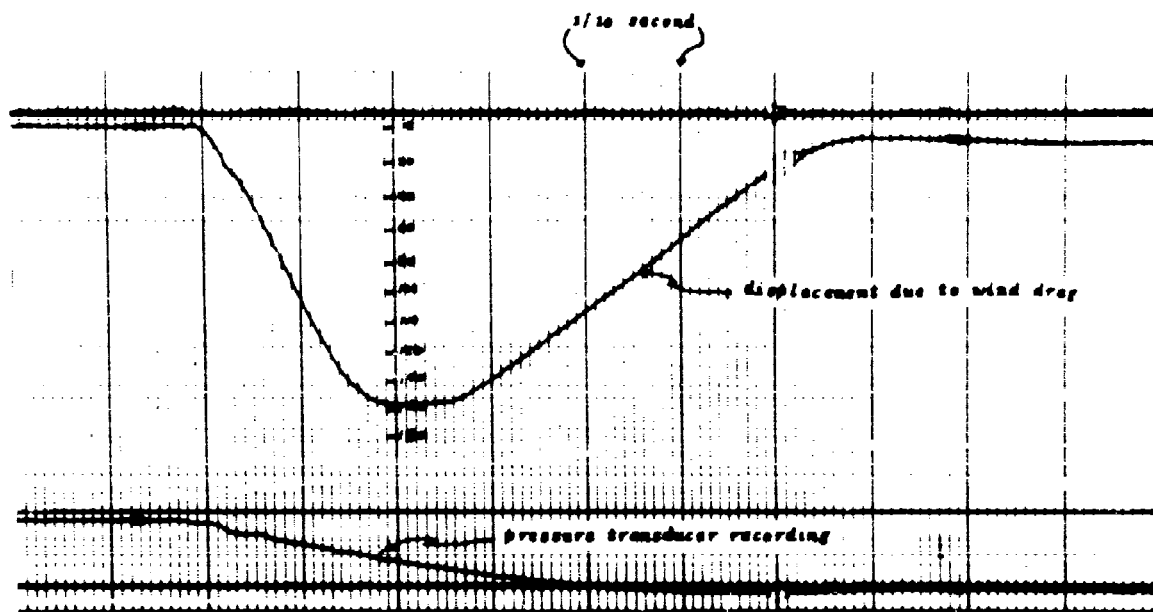
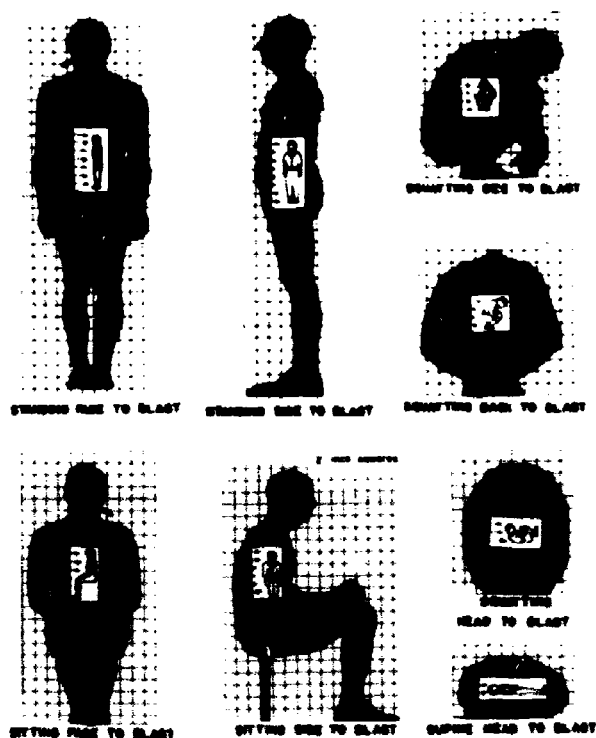


FIGURE 2. Mockup for measuring forces of wind blast on human subjects.



SAMPLE OSCILLOGRAPH TRACING

FIGURE 3. Sample oscillograph tracing.



PROJECTED AREAS OF HUMAN SUBJECTS

FIGURE 4. Projected areas of human subjects.

TABLE I.
Wind Blast Forces on the Human Body (Phase 1)

Body Position	Subject	Force (in lbs) average 5-A trials	Projected Body Area (Sq. Ft.)	Equivalent Flat Plate Area (Sq. Ft.)	AI/AP
Standing back to blast	S	177.3	6.38	4.95	.76
	M	217.0	7.44	5.23	.70
	A	164.8	6.08	4.68	.77
	B	162.6	6.08	4.63	.76
	C	193.3	6.27	5.02	.72
	Av.	183.0	6.59	4.99	
Standing face to blast	S	156.2	6.38	4.53	.71
	M	185.0	7.44	4.73	.66
	A	152.8	6.28	4.45	.73
	B	146.6	6.08	4.35	.72
	C	171.6	6.97	4.78	.69
	Av.	162.4	6.50	4.60	
Standing side to blast	S	66.4	3.88	2.48	.64
	M	79.0	4.61	2.83	.61
	A	74.2	3.91	2.70	.69
	B	3.0	3.97	2.65	.67
	C	82.6	4.52	2.92	.65
	Av.	75.1	4.18	2.71	
Sitting back to blast	S	86.0	4.27	3.00	.70
	M	94.4	4.74	3.23	.65
	A	80.6	4.19	2.88	.69
	B	106.2	4.27	3.51	.82
	C	105.4	4.63	3.49	.75
	Av.	94.5	4.46	3.22	
Sitting face to blast	S	84.2	4.27	2.97	.70
	M	107.4	4.94	3.53	.71
	A	90.2	4.19	3.13	.75
	B	90.0	4.27	3.12	.73
	C	105.0	4.63	3.48	.75
	Av.	95.4	4.46	3.24	
Sitting side to blast	S	72.0	4.02	2.63	.65
	M	77.6	4.77	2.79	.58
	A	64.6	3.83	2.42	.63
	B	76.2	3.91	2.75	.70
	C	76.0	4.33	2.74	.63
	Av.	73.2	4.17	2.66	
Squatting back to blast	S	47.6	3.50	1.88	.54
	M	50.6	3.88	1.98	.51
	A	45.5	2.52	1.81	.72
	B	50.6	2.72	1.98	.73
	C	53.8	3.61	2.08	.58
	Av.	49.6	3.25	1.94	
Squatting face to blast	S	64.0	3.50	2.40	.69
	M	102.6	3.88	3.42	.88
	A	55.8	2.52	2.08	.83
	B	76.5	2.72	2.75	1.01
	C	72.8	3.61	2.65	.73
	Av.	73.9	3.25	2.66	
Squatting side to blast	S	62.2	3.61	2.35	.65
	M	84.6	4.47	2.98	.67
	A	74.8	3.54	2.72	.77
	B	78.4	4.05	2.82	.70
	C	76.4	4.02	2.76	.69
	Av.	75.2	3.94	2.72	
Squatting head to blast	S	38.0	2.86	1.54	.54
	M	44.2	3.52	1.77	.50
	A	38.4	2.45	1.57	.64
	B	41.8	2.90	1.68	.58
	C	53.4	3.43	2.07	.60
	Av.	43.1	3.03	1.72	
Supine head to blast	S	43.2	1.37	1.73	1.26
	M	55.2	2.02	2.13	1.06
	A	45.2	1.22	1.40	1.48
	B	44.6	1.44	1.77	1.23
	C	55.2	1.72	2.13	1.24
	Av.	48.6	1.55	1.91	

carriage mount, one end of which was linked to a heavy steel spring to which strain gauges were affixed for measurement of forces (Fig. 2). Table I summarized the averages of five to eight trials on each of five experimental subjects. Eleven different body positions were tested. It was expected that the forces acting on the body would vary between subjects and would be roughly related to body sizes.

The column "Projected Body Area" of Table I represents the area of the silhouette of each subject in each position assumed.

Measurements were also made of the forces acting on a series of flat plates of various sizes placed in the wind tunnel on the human subject carriage. These are shown graphically in Fig. 5. The third column of figures in Table I represents the flat plate area equivalent of the force measured on the human subject. The last column of Table I represents the ratio of the equivalent flat plate area to the projected area of the body.

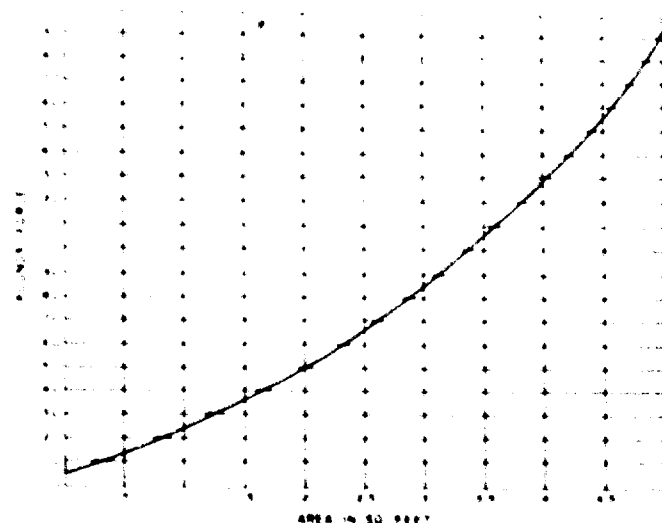


FIGURE 5. Flat plate resistance to wind blast (33 cm Hg Diff.).

TABLE II
Summary of Force Data Obtained in Wind Blast Study (Phase 2)

Subject	Position	Projected Area (sq ft)	Force (lb)	Ratio
1	1	1.5	10	6.7
1	2	2.0	15	7.5
1	3	2.5	20	8.0
1	4	3.0	25	8.3
1	5	3.5	30	8.6
1	6	4.0	35	8.8
1	7	4.5	40	9.0
1	8	5.0	45	9.2
1	9	5.5	50	9.4
1	10	6.0	55	9.6
1	11	6.5	60	9.8
1	12	7.0	65	10.0
1	13	7.5	70	10.2
1	14	8.0	75	10.4
1	15	8.5	80	10.6
1	16	9.0	85	10.8
1	17	9.5	90	11.0
1	18	10.0	95	11.2
1	19	10.5	100	11.4
1	20	11.0	105	11.6
1	21	11.5	110	11.8
1	22	12.0	115	12.0
1	23	12.5	120	12.2
1	24	13.0	125	12.4
1	25	13.5	130	12.6
1	26	14.0	135	12.8
1	27	14.5	140	13.0
1	28	15.0	145	13.2
1	29	15.5	150	13.4
1	30	16.0	155	13.6
1	31	16.5	160	13.8
1	32	17.0	165	14.0
1	33	17.5	170	14.2
1	34	18.0	175	14.4
1	35	18.5	180	14.6
1	36	19.0	185	14.8
1	37	19.5	190	15.0
1	38	20.0	195	15.2
1	39	20.5	200	15.4
1	40	21.0	205	15.6
1	41	21.5	210	15.8
1	42	22.0	215	16.0
1	43	22.5	220	16.2
1	44	23.0	225	16.4
1	45	23.5	230	16.6
1	46	24.0	235	16.8
1	47	24.5	240	17.0
1	48	25.0	245	17.2
1	49	25.5	250	17.4
1	50	26.0	255	17.6
1	51	26.5	260	17.8
1	52	27.0	265	18.0
1	53	27.5	270	18.2
1	54	28.0	275	18.4
1	55	28.5	280	18.6
1	56	29.0	285	18.8
1	57	29.5	290	19.0
1	58	30.0	295	19.2
1	59	30.5	300	19.4
1	60	31.0	305	19.6
1	61	31.5	310	19.8
1	62	32.0	315	20.0
1	63	32.5	320	20.2
1	64	33.0	325	20.4
1	65	33.5	330	20.6
1	66	34.0	335	20.8
1	67	34.5	340	21.0
1	68	35.0	345	21.2
1	69	35.5	350	21.4
1	70	36.0	355	21.6
1	71	36.5	360	21.8
1	72	37.0	365	22.0
1	73	37.5	370	22.2
1	74	38.0	375	22.4
1	75	38.5	380	22.6
1	76	39.0	385	22.8
1	77	39.5	390	23.0
1	78	40.0	395	23.2
1	79	40.5	400	23.4
1	80	41.0	405	23.6
1	81	41.5	410	23.8
1	82	42.0	415	24.0
1	83	42.5	420	24.2
1	84	43.0	425	24.4
1	85	43.5	430	24.6
1	86	44.0	435	24.8
1	87	44.5	440	25.0
1	88	45.0	445	25.2
1	89	45.5	450	25.4
1	90	46.0	455	25.6
1	91	46.5	460	25.8
1	92	47.0	465	26.0
1	93	47.5	470	26.2
1	94	48.0	475	26.4
1	95	48.5	480	26.6
1	96	49.0	485	26.8
1	97	49.5	490	27.0
1	98	50.0	495	27.2
1	99	50.5	500	27.4
1	100	51.0	505	27.6
1	101	51.5	510	27.8
1	102	52.0	515	28.0
1	103	52.5	520	28.2
1	104	53.0	525	28.4
1	105	53.5	530	28.6
1	106	54.0	535	28.8
1	107	54.5	540	29.0
1	108	55.0	545	29.2
1	109	55.5	550	29.4
1	110	56.0	555	29.6
1	111	56.5	560	29.8
1	112	57.0	565	30.0
1	113	57.5	570	30.2
1	114	58.0	575	30.4
1	115	58.5	580	30.6
1	116	59.0	585	30.8
1	117	59.5	590	31.0
1	118	60.0	595	31.2
1	119	60.5	600	31.4
1	120	61.0	605	31.6
1	121	61.5	610	31.8
1	122	62.0	615	32.0
1	123	62.5	620	32.2
1	124	63.0	625	32.4
1	125	63.5	630	32.6
1	126	64.0	635	32.8
1	127	64.5	640	33.0
1	128	65.0	645	33.2
1	129	65.5	650	33.4
1	130	66.0	655	33.6
1	131	66.5	660	33.8
1	132	67.0	665	34.0
1	133	67.5	670	34.2
1	134	68.0	675	34.4
1	135	68.5	680	34.6
1	136	69.0	685	34.8
1	137	69.5	690	35.0
1	138	70.0	695	35.2
1	139	70.5	700	35.4
1	140	71.0	705	35.6
1	141	71.5	710	35.8
1	142	72.0	715	36.0
1	143	72.5	720	36.2
1	144	73.0	725	36.4
1	145	73.5	730	36.6
1	146	74.0	735	36.8
1	147	74.5	740	37.0
1	148	75.0	745	37.2
1	149	75.5	750	37.4
1	150	76.0	755	37.6
1	151	76.5	760	37.8
1	152	77.0	765	38.0
1	153	77.5	770	38.2
1	154	78.0	775	38.4
1	155	78.5	780	38.6
1	156	79.0	785	38.8
1	157	79.5	790	39.0
1	158	80.0	795	39.2
1	159	80.5	800	39.4
1	160	81.0	805	39.6
1	161	81.5	810	39.8
1	162	82.0	815	40.0
1	163	82.5	820	40.2
1	164	83.0	825	40.4
1	165	83.5	830	40.6
1	166	84.0	835	40.8
1	167	84.5	840	41.0
1	168	85.0	845	41.2
1	169	85.5	850	41.4
1	170	86.0	855	41.6
1	171	86.5	860	41.8
1	172	87.0	865	42.0
1	173	87.5	870	42.2
1	174	88.0	875	42.4
1	175	88.5	880	42.6
1	176	89.0	885	42.8
1	177	89.5	890	43.0
1	178	90.0	895	43.2
1	179	90.5	900	43.4
1	180	91.0	905	43.6
1	181	91.5	910	43.8
1	182	92.0	915	44.0
1	183	92.5	920	44.2
1	184	93.0	925	44.4
1	185	93.5	930	44.6
1	186	94.0	935	44.8
1	187	94.5	940	45.0
1	188	95.0	945	45.2
1	189	95.5	950	45.4
1	190	96.0	955	45.6
1	191	96.5	960	45.8
1	192	97.0	965	46.0
1	193	97.5	970	46.2
1	194	98.0	975	46.4
1	195	98.5	980	46.6
1	196	99.0	985	46.8
1	197	99.5	990	47.0
1	198	100.0	995	47.2
1	199	100.5	1000	47.4
1	200	101.0	1005	47.6
1	201	101.5	1010	47.8
1	202	102.0	1015	48.0
1	203	102.5	1020	48.2
1	204	103.0	1025	48.4
1	205	103.5	1030	48.6
1	206	104.0	1035	48.8
1	207	104.5	1040	49.0
1	208	105.0	1045	49.2
1	209	105.5	1050	49.4
1	210	106.0	1055	49.6
1	211	106.5	1060	49.8
1	212	107.0	1065	50.0
1	213	107.5	1070	50.2
1	214	108.0	1075	50.4
1	215	108.5	1080	50.6
1	216	109.0	1085	50.8
1	217	109.5	1090	51.0
1	218	110.0	1095	51.2
1	219	110.5	1100	51.4
1	220	111.0	1105	51.6
1	221	111.5	1110	51.8
1	222	112.0	1115	52.0
1	223	112.5	1120	52.2
1	224	113.0	1125	52.4
1	225	113.5	1130	52.6
1	226	114.0	1135	52.8
1	227	114.5	1140	53.0
1	228	115.0	1145	53.2
1	229	115.5	1150	53.4
1	230	116.0	1155	53.6
1	231	116.5	1160	53.8
1	232	117.0	1165	54.0
1	233	117.5	1170	54.2
1	234	118.0	1175	54.4
1	235	118.5	1180	54.6
1	236	119.0	1185	54.8
1	237	119.5	1190	55.0
1	238	120.0	1195	55.2
1	239	120.5	1200	55.4
1	240	121.0	1205	55.6
1	241	121.5	1210	55.8
1	242	122.0	1215	56.0
1	243	122.5	1220	56.2
1	244	123.0	1225	56.4
1	245	123.5	1230	56.6
1	246	124.0	1235	56.8
1	247	124.5	1240	57.0
1	248	125.0	1245	57.2
1	249	125.5	1250	57.4
1	250	126.0	1255	57.6
1	251	126.5	1260	57.8
1	252	127.0	1265	58.0
1	253	127.5	1270	58.2
1	254	128.0	1275	58.4
1	255	128.5	1280	58.6
1	256	129.0	1285	58.8
1	257	1		

PHASE 2. BLAST FORCES PRODUCING DISORIENTATION

Another series of fifty tests was made on one subject (clothed) as an initial step in the accumulation of data on the forces required to disorient man from standing and seated posture, and while walking with face, back and side to the blast. In these tests repeat measurements were made of the maximum forces acting on the human body at successive increments of window pressure differential. These pressure differentials on the window ranged from 5.5 to 44.0 cm Hg, in 5.5 cm Hg increments. After establishing these values for the single subject, he assumed the same positions in the wind tunnel without attachment to strain gauges or other force measuring devices. The subject was secured by a safety belt and slack cable to minimize the danger of bodily injury. A series of trials was made increasing the pressure differential in successive trials until the subject was unable to maintain balance or to recover. The criteria for not being able to recover his body position was falling beyond a possible point of balance at the extreme range of the safety harness. Table II shows the effect of wind blast upon maintenance of body posture. Table III presents force calibration measurements on the subject at eight window pressure differentials.

TABLE III

Changes of Wind Blast Forces (lb) on the Human Body Due to Changes of Pressure Differential

Subject: A

Differential pressure in cm Hg	Standing			Sitting		
	Back to blast	Face to blast	Side to blast	Back to blast	Face to blast	Side to blast
5.5	21	12	2	0	7	6
11.0	69	59	14	25	31	20
16.5	116	96	29	47	45	37
22.0	143	125	48	58	63	55
27.5	166	154	75	71	77	63
33.0	174	172	77	84	82	75
38.5	179	180	85	88	86	80
44.0	184	182	82	92	91	85

PHASE 3. EFFECTS OF CLOTHING ON DRAG FORCES

The final phase was concerned with the effects of clothing on the drag of the human body. To determine the component of the drag forces presented in Phases 1 and 2 which could be attributed to the clothing, additional tests were made with subjects wearing shorts and shoes. Results are reproduced in Table IV and show that drag forces are 17-22 per cent less for nude individuals. This difference in drag for clothed and nude subjects has been confirmed in wind tunnel studies by Schmitt¹ who found 17-20 per cent difference during long exposures to constant air loads.

TABLE IV

Effects of Clothing on Drag Forces, Standing Back to Blast, 33 cm Hg Diff.

	With shirt, trousers and shoes	With shorts and shoes	Difference
Subject A	177.0 lb 177.3*	138.0 lb 138.0	39 lb
Subject B	177.0 162.6*	140.0 139.0	37
Subject C	210.0 193.3*	173.0 173.0	37

*Average of numerous trials in Phase 1.

AERODYNAMICS OF MAN

The experimental results reported in the previous section were obtained during very brief exposures to air loads. Because it was desirable to know whether these results would hold during long exposures and for related reasons, the Aerodynamics Laboratory of the David W. Taylor Model Basin was approached through the Navy Department and agreed to make aerodynamic measurements on human subjects in their wind tunnel. Schmitt¹ reported the findings obtained in tests done in collaboration with FAA personnel. Drag coefficients and lift, side force and moments to indicate relative trends of motion for each of five body positions (standing, sitting, supine and two squat positions) were determined.

The drag coefficients (C_d) which are of more immediate application to the purpose of the present report are given in terms of the body parameter vH/S which was selected from five trial parameters as giving the least variation in drag coefficients (v = volume of the body in ft^3 , H = height in ft , S = body surface area in ft^2). The values of this parameter for the 16 subjects of these tests varied from 0.65 to 0.82 ft^3 , with a mean value for the group of 0.72 ft^3 .

Schmitt also reported dynamic pressures (q) with corresponding airspeeds and Reynolds numbers. These are reproduced in Table V. Drag coefficients were found to be practically independent of the Reynolds number within the range of test, except below a Reynolds number of 0.5×10^6 , where a sharp increase in drag coefficient was found.

TABLE V

Summary of Test Dynamic Pressures with Approximate Corresponding Airspeeds and Reynolds Numbers

q lb/ft ²	V		
	ft/sec	knots	$R \times 10^{-6}$
1.0	30.1	17.8	0.17
9.0	90.2	53.4	0.51
26.0	153	90.8	0.87
37.0	183	108	1.04
43.0	195	116	1.14
50.0	212	126	1.21
58.0	227	134	1.32
66.0	243	144	1.39

With the above information, drag force (D) can be calculated from the determined coefficients of drag using the equation, $D = C_d \times (vH/S) \times q$. This calculation, of course, requires that the airspeed which is needed to obtain values for q be known.

Unfortunately, airspeed values at various points in an airplane or other pressurized vessel undergoing decompression are not usually available. However, some estimate of airspeeds can generally be made. For example, in the studies on the physical displacement of man reported

in the previous section, the following reasoning may be applied: (a) since the ratio of the area of the ruptured window to the cross-sectional area of the corridor or "wind tunnel" was approximately 0.13, the airspeed in the corridor was 0.35 of that at the window, (b) the airspeed at the window may be estimated at 886 ft/sec from the equation for the efflux of gases ($v = \sqrt{2P/p}$) and (c) the airspeed in the unoccupied tunnel was about $0.13 \times 886 = 118 \text{ ft/sec}$. Using this estimate of airspeed and the mean value of 0.72 for vH/S , drag forces are calculated from the DTMB data and compared in Table VI with the data on clothed subjects given in the section on the physical displacement of man. Excepting the supine position, there is agreement between the ob-

TABLE VI

Comparing Calculated Drag Forces From Wind Tunnel Tests With Observed Values in Short Duration Blast Studies

Posture	Angle	Drag coeff. (DTMB data)	Drag		Obs Calc
			Calc	Obs	
Standing	0	12.0	136	162	1.2
	90	5.0	57	75	1.3
	180	11.0	125	183	1.5
Sitting	0	7.8	88	95	1.1
	90	4.4	50	73	1.5
	180	7.0	79	95	1.2
Supine	0	1.5	17	49	2.9
Squat No. 1	180	2.5	28	43	1.5
Squat No. 2	0	4.3	49	74	1.5
	90	3.5	40	75	1.9
	180	3.0	34	50	1.5

served and calculated values. More experience in this relatively unexplored field is needed to judge how well calculated and observed results might be expected to agree in such a situation. For example, the method used to calculate airspeed at the point of entry to the corridor would have over-estimated this quantity. This over-estimate may have approximately compensated for the fact that the subjects occupied an appreciable portion of the cross-sectional area of the corridor.

In any event it should not be inferred from the above results that forces on the body due to air movement can be readily calculated from the DTMB data for all practical situations. Actually, such calculations only apply accurately to conditions of uniform airspeed in a relatively unconfined space. In such practical situations as are discussed in this report in connection with airplane decompression, it cannot necessarily be assumed that such conditions are approached. An extreme example of a situation in which these calculations could not be used would be the case where an opening was completely occluded by a person. In this case, the force on the body would be estimated by multiplying static pressure by the area of the body involved. However, except for such an extreme case, the DTMB data can be used to make order-of-magnitude estimates which are helpful, for example, in designing experiments to measure directly the magnitude of force that air movement exerts on man in particular situations.

APPENDIX

Calculation of Airloads on Man Standing Near A Door During Decompression Due to Door Failure

The values needed for calculating drag force from the equation, $D = (\rho H/S) \times C_D \times q$ are given below:

$$\frac{\rho H}{S} = 0.71$$

$$C_D = 11 \text{ (from the DTMB report)}$$

NOTE: This is the value for a clothed individual facing the door.

To obtain q , an estimate must be made of the airspeed at the point where the subject stood. The velocity at the door may be taken as 886 ft/sec according to a previous estimate for a pressure differential of 6.5 lb/in² (see test). The effective cross-sectional area where

the subject stood can be taken as a first approximation to be equal to the width of the door (37 in.) \times the height of the chamber (96 in.) or 3552 in.² plus twice the length of a quarter circle 30 in. in radius \times the height of the chamber or 9043 in.², which gives a total of 12,595 in.². A 30 in. radius instead of a 24 in. radius (the distance between the frontal plane of the subject and the door) is taken to allow for the thickness of the body. In this approximation, the two quarters of the cylindrical surface are visualized as being positioned at the two sides of the door. The area of the doorway is 2886 in.² or 0.23 of the effective area, which gives an estimated airspeed at this point of 0.23×886 or 204 ft/sec, and a q value of 47 lb/ft².

Substituting these values, we have

$$D = 0.71 \times 11 \times 47 = 367 \text{ lb}$$

This value is considerably greater than the 166-174 lb (Table II) force found necessary to displace a person standing with his back to the wind. The explanation of this discrepancy presumably is that the duration of airload in the experiments facing the door was shorter than the duration of airloads in which the forces causing body displacement were measured. As suggested in the text, considerable judgment must be used in applying to a given situation experimental data obtained under other conditions, or in using drag coefficients to calculate reliable estimates of forces.

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